PART 4

PINCH DESIGN METHOD

MAXIMUM ENERGY RECOVERY NETWORKS

MER NETWORKS

- Networks featuring minimum utility usage are called MAXIMUM ENERGY RECOVERY (MER) Networks.

DIVISION AT THE PINCH

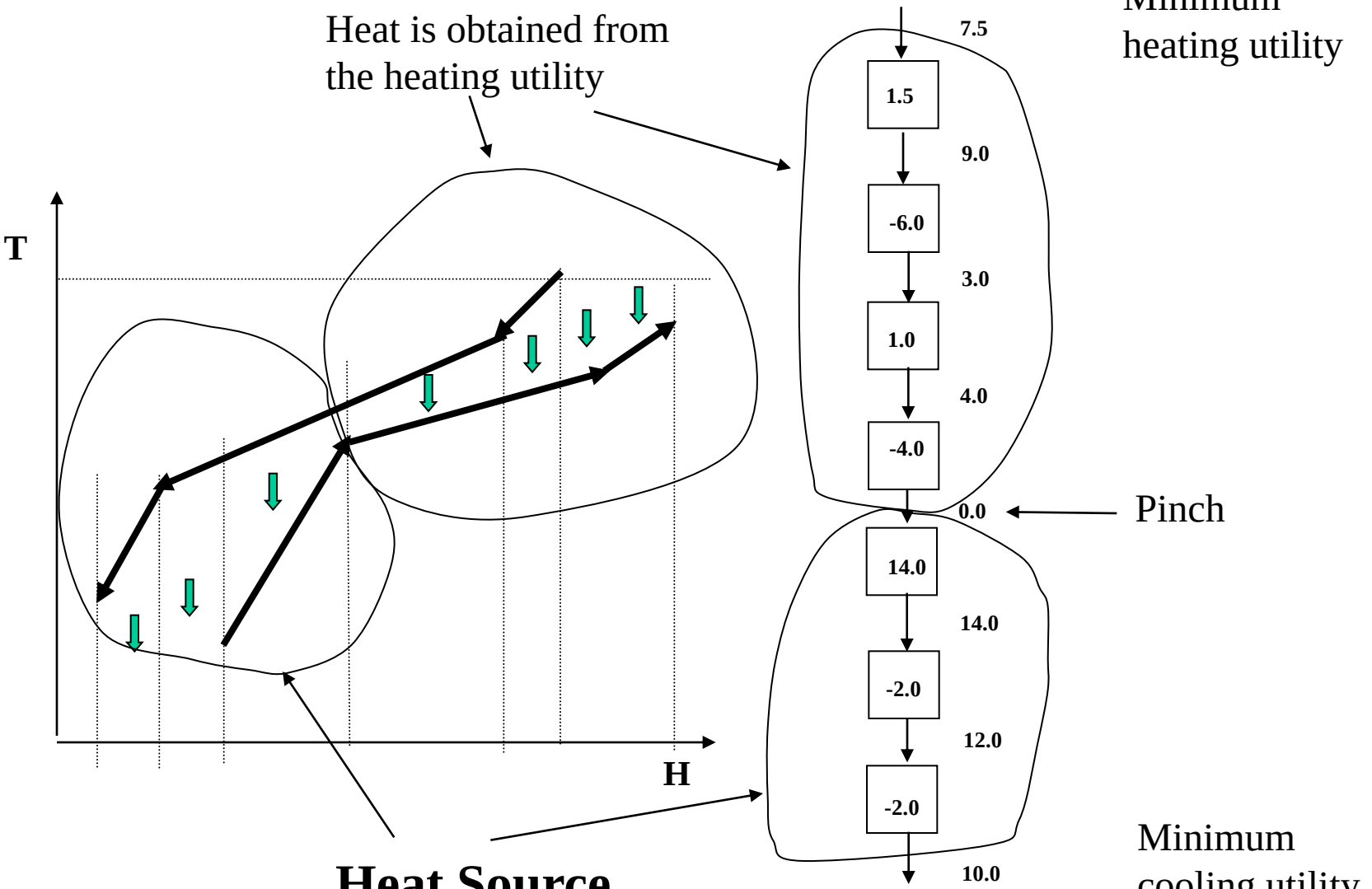
RECALL THAT

- No heat is transferred through the pinch.
- This makes the region above the pinch a HEAT SINK region and the region below the pinch a HEAT SOURCE region.

Heat Sink

Heat is obtained from the heating utility

Minimum heating utility



Heat Source

Heat is released to cooling utility

Minimum cooling utility

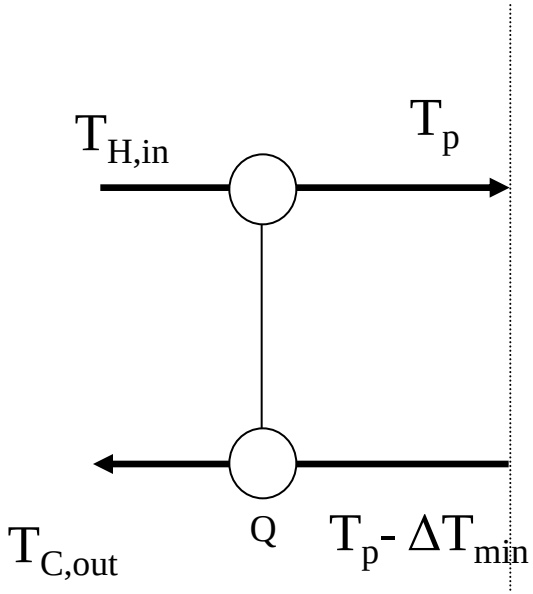
CONCLUSION

- One can analyze the two systems separately, that is,

- Heat exchangers will not match streams above the pinch with streams below the pinch

PINCH MATCHES

- Consider two streams above the pinch



$$T_{C,out} = T_p - \Delta T_{min} + Q/FCp_C$$

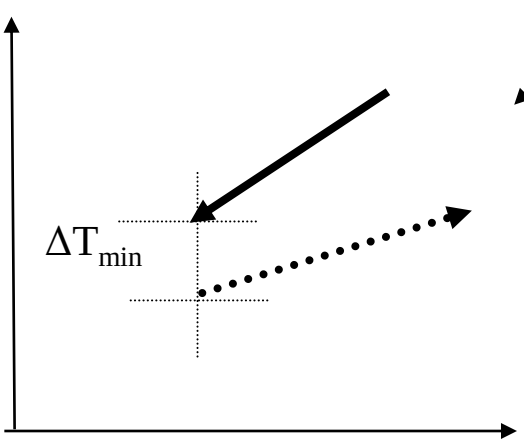
$$T_{H,in} = T_p + Q/FCp_H$$

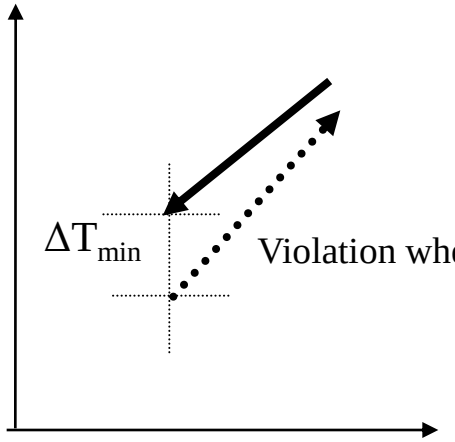
But $T_{H,in} > T_{C,out} + \Delta T_{min}.$

Thus replacing one obtains $Q/FCp_H > Q/FCp_C$

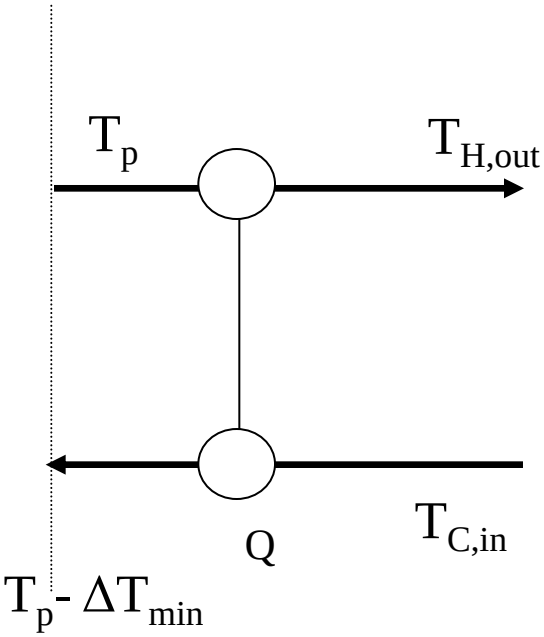
$$FCp_H < FCp_C$$

Golden rule for pinch matches above the pinch.





Below the Pinch



$$T_{C,in} = T_p - \Delta T_{min} - Q/FCp_C$$

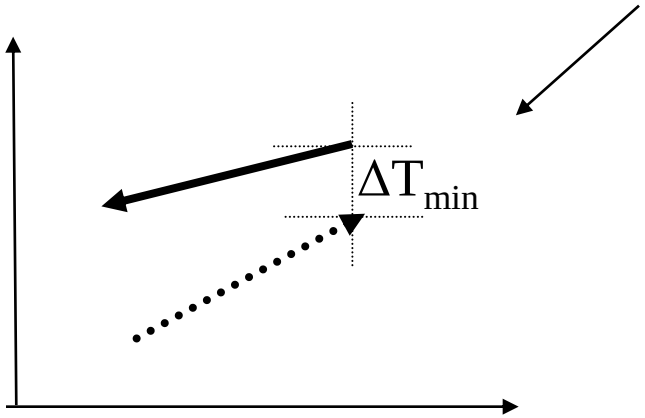
$$T_{H,out} = T_p - Q/FCp_H$$

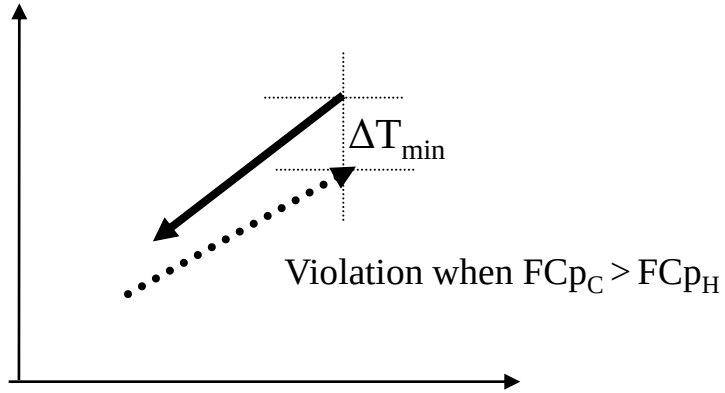
But $T_{H,out} > T_{C,in} + \Delta T_{min.}$

Thus replacing one obtains

$$FCp_C < FCp_H$$

Golden rule for pinch matches below the pinch.





CONCLUSION

- Since matches at the pinch need to satisfy these rules, one should start locating these matches first. Thus, our first design rule:

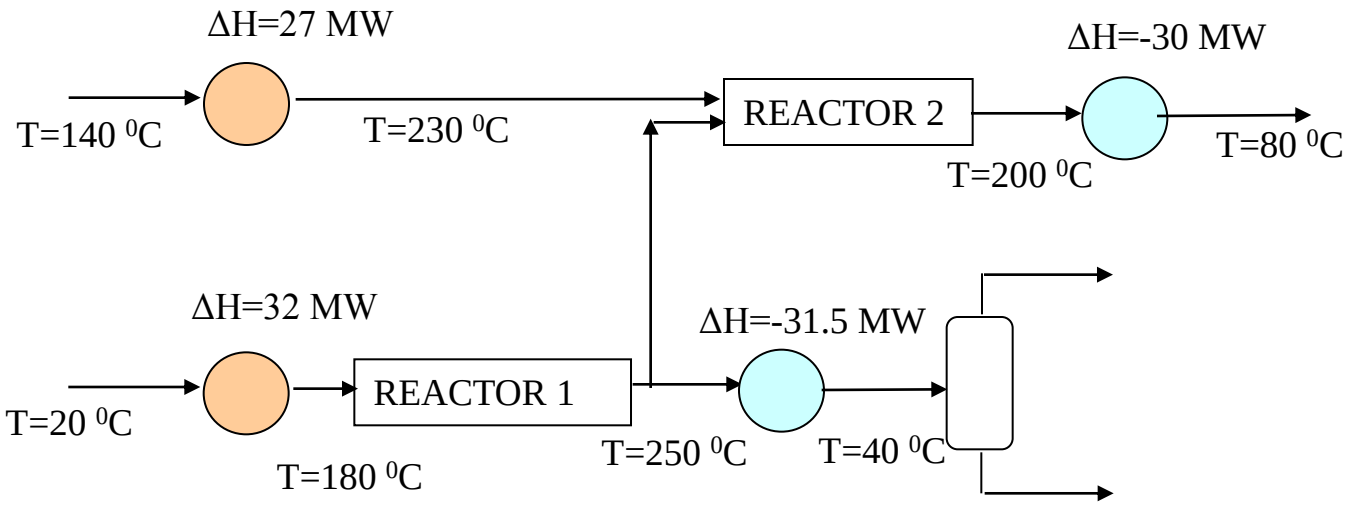
START BY MAKING PINCH MATCHES

TICK-OFF RULE

Once a match has been selected how much heat should be exchanged?

- As much as possible! (We want to minimize units, so once we have one, we make the biggest use of it possible)
- This means that one of the streams has its duty satisfied!!

HANDS ON EXERCISE

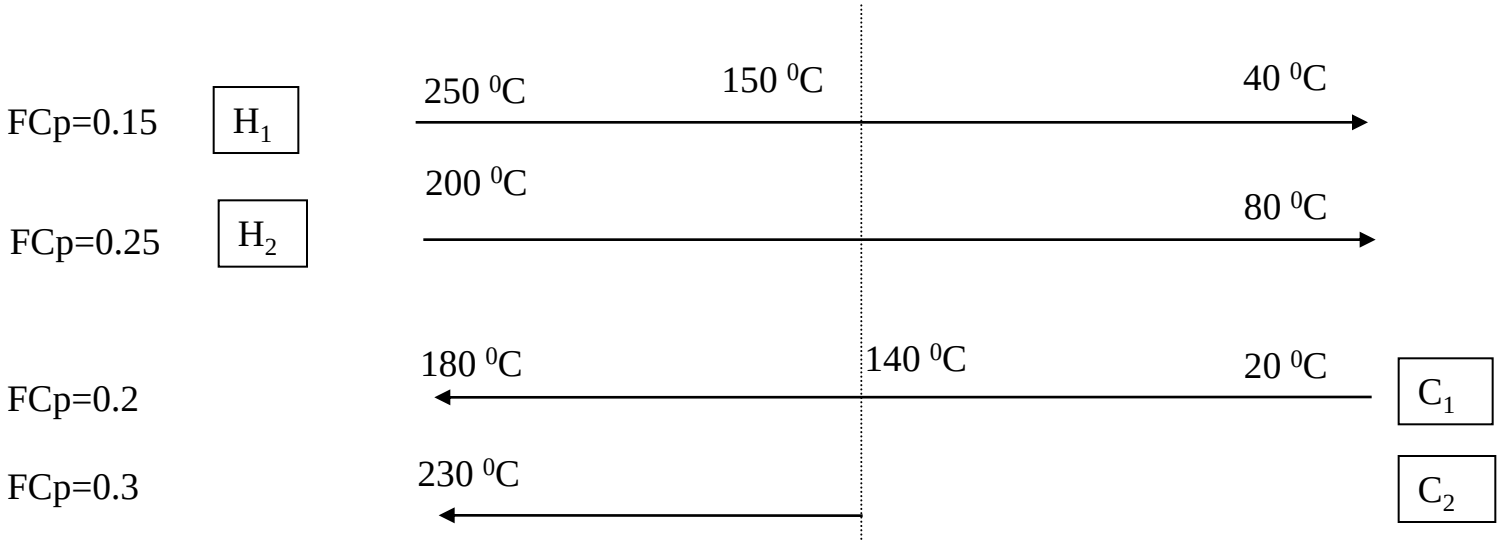


Stream	Type	Supply T (°C)	Target T (°C)	ΔH (MW)	F*Cp (MW °C^{-1})
Reactor 1 feed	Cold	20	180	32.0	0.2
Reactor 1 product	Hot	250	40	-31.5	0.15
Reactor 2 feed	Cold	140	230	27.0	0.3
Reactor 2 product	Hot	200	80	-30.0	0.25

ΔT_{min}=10 °C

PINCH=150 °C

HANDS ON EXERCISE



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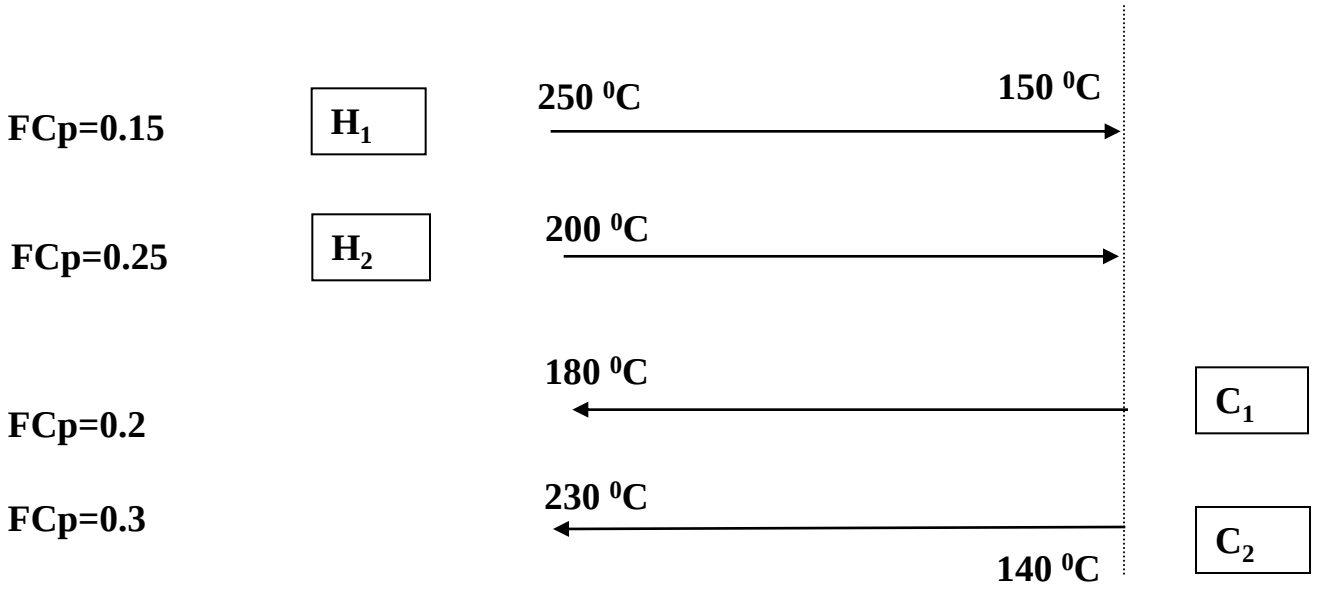
ΔT_{min}=10 °C

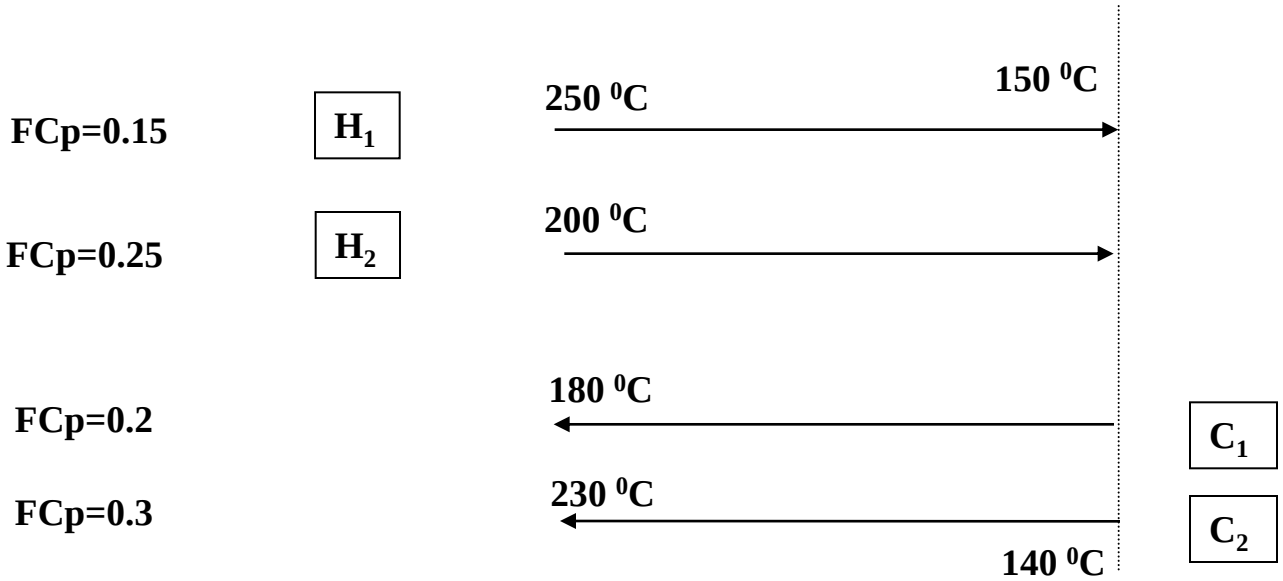
PINCH=150 °C

ABOVE THE PINCH



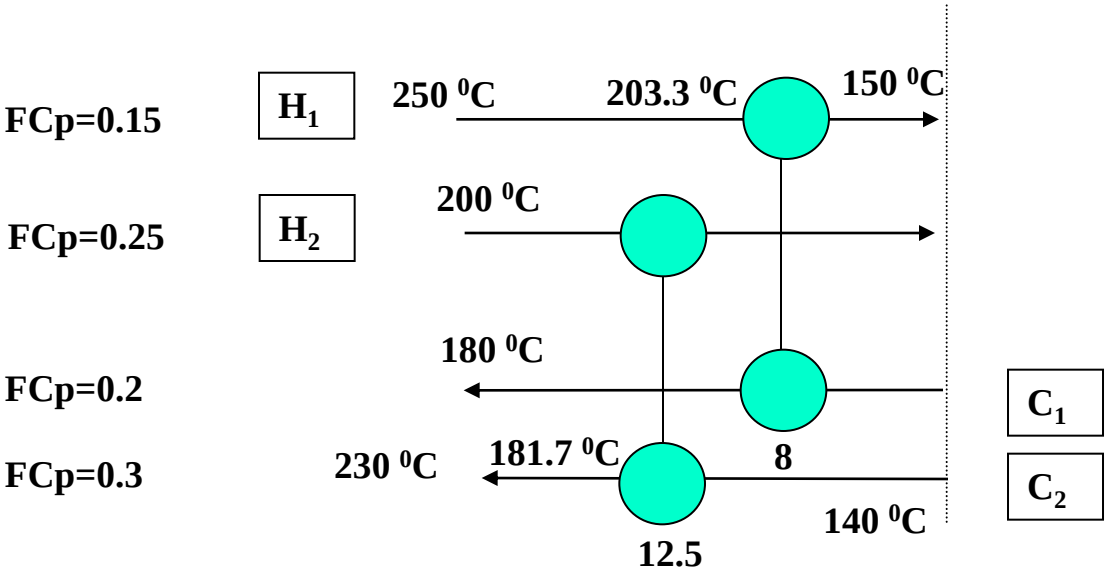
- Which matches are possible?

Pinch matches above the Pinch



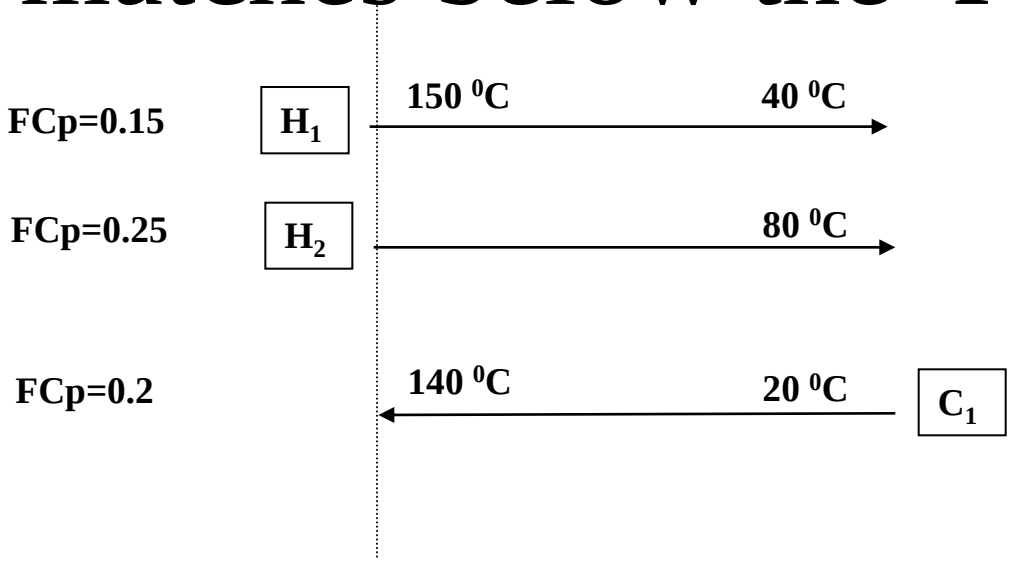
- The rule is that $FCp_H < FCp_C$.
- The candidates are: H1-C1, H1-C2 and H2-C2.
- Because all hot streams at the pinch need to participate in a pinch match, we therefore can only choose the matches H1-C1 and H2-C2.

Pinch matches above the Pinch



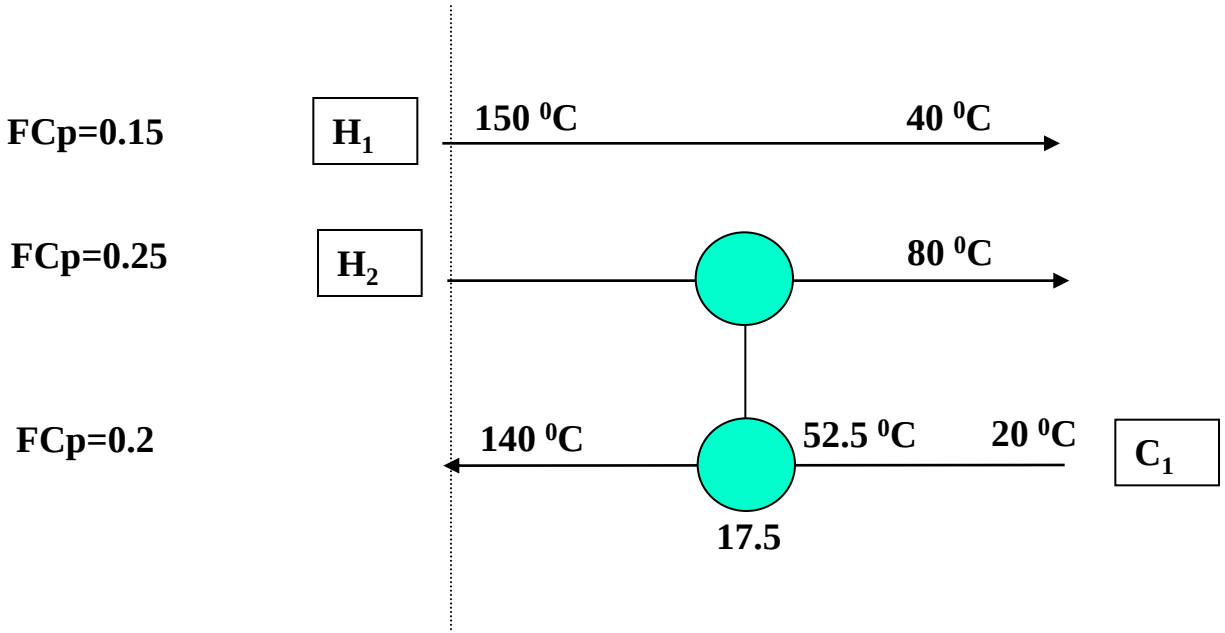
- The tick-off rule says that a maximum of 8 MW is exchanged in the match H1-C1 and as a result stream C1 reaches its target temperature.
- Similarly 12.5 MW are exchanged in the other match and the stream H2 reaches the pinch temperature.

Pinch matches below the Pinch



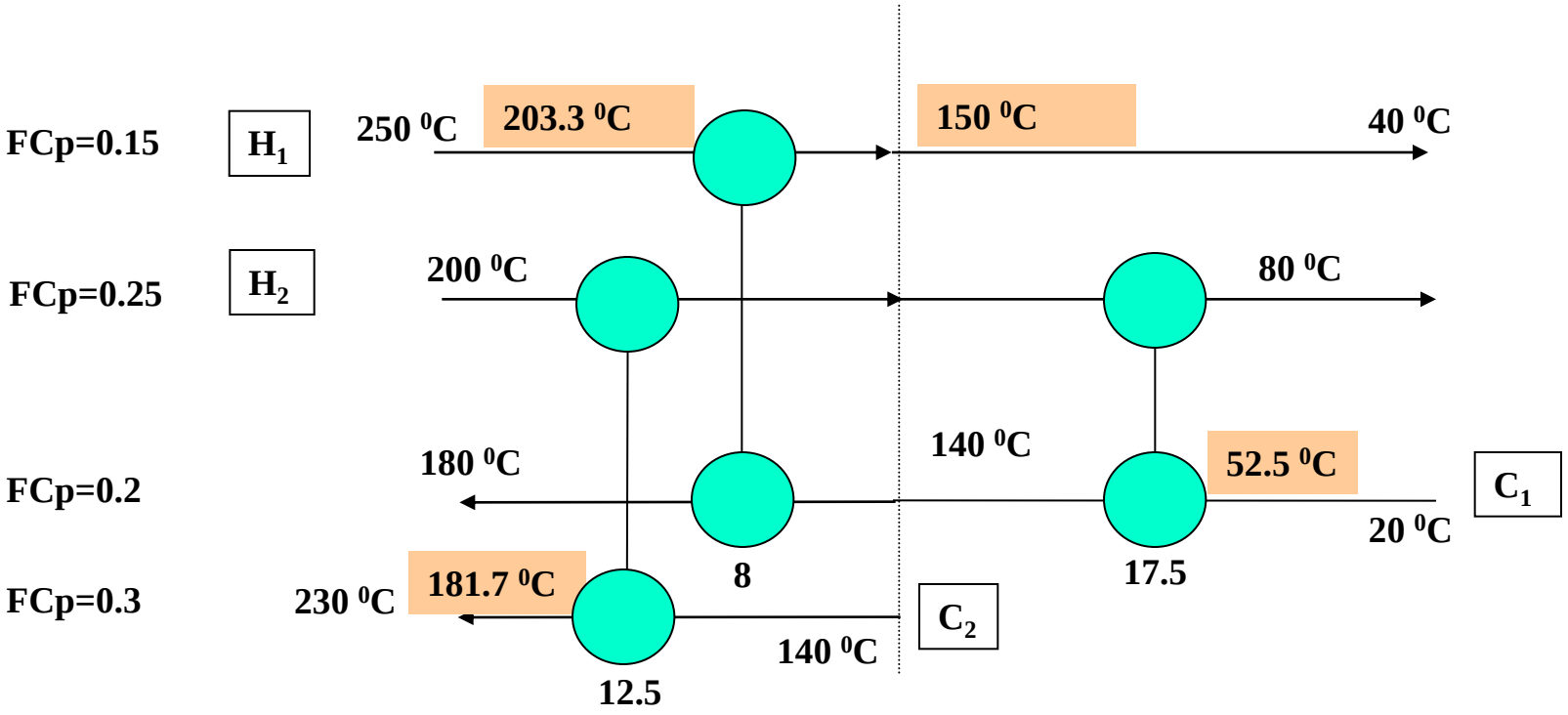
- The rule is that $FCp_C < FCp_H$.
- Only one match qualifies: H2-C1
- Below the pinch all cold streams need to participate in pinch matches

ANSWER (below the pinch)



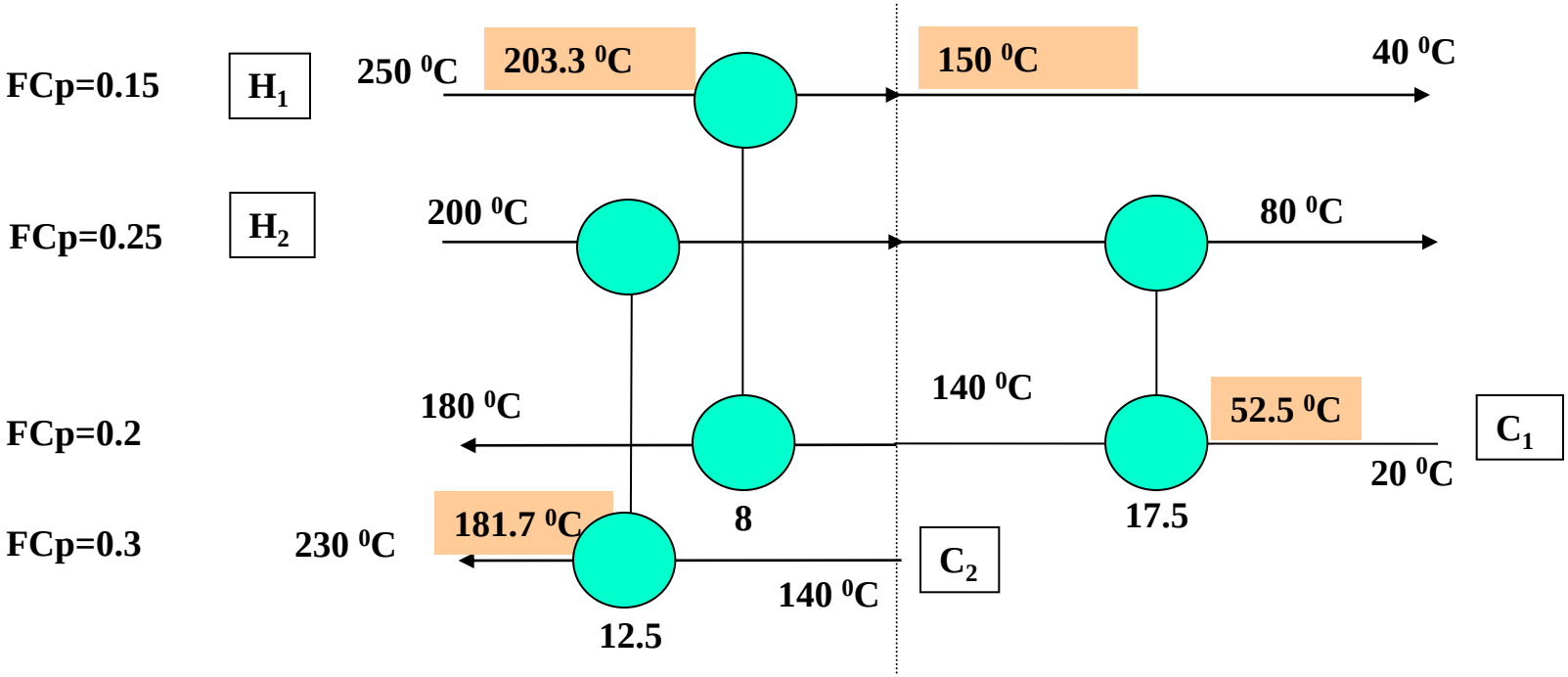
- The tick-off rule says that a maximum of 17.5 MW is exchanged in the match H2-C1 and as a result stream H2 reaches its target temperature.

COMPLETE NETWORK AFTER PINCH MATCHES



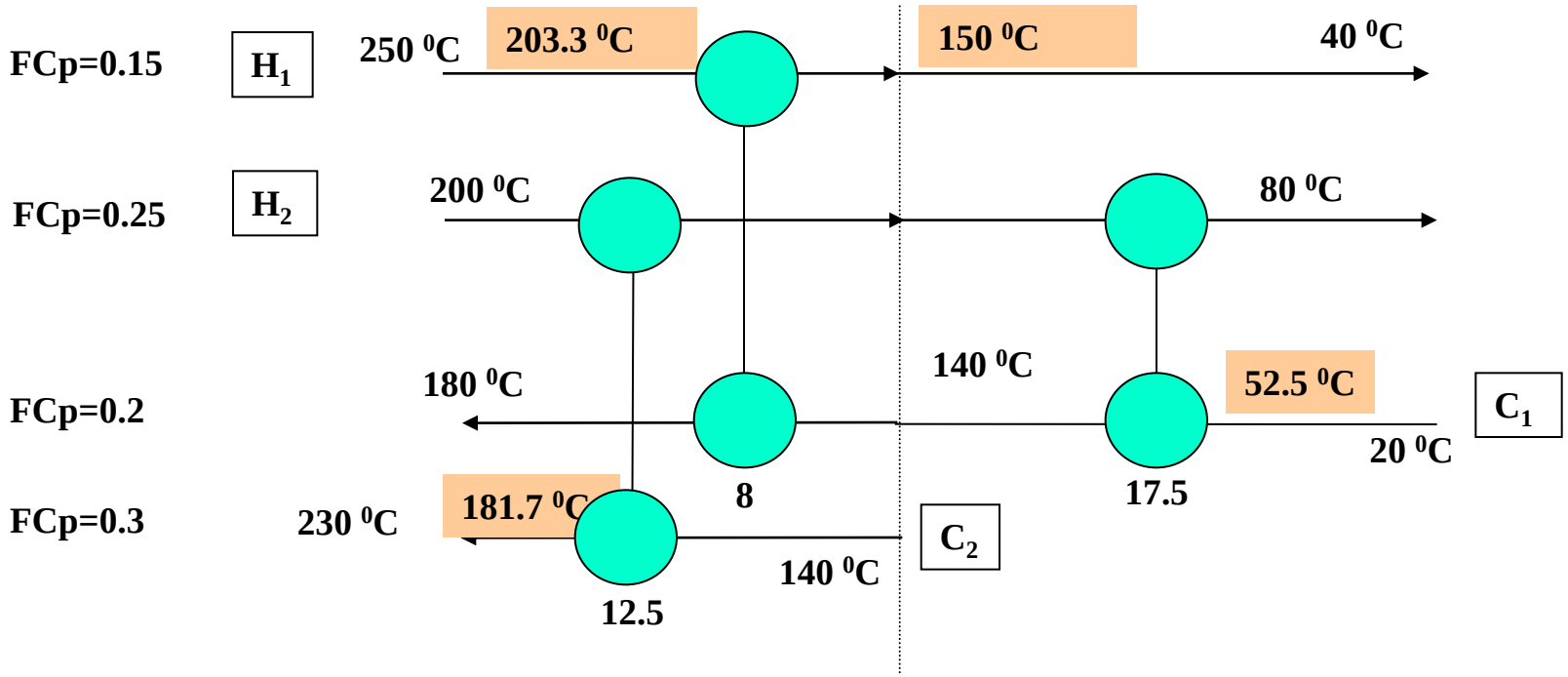
- Streams with unfulfilled targets are colored.

NON-PINCH MATCHES



- **Away from the pinch, there is more flexibility to make matches, so the inequalities do not have to hold.**
- **The pinch design method leaves you now on your own!!!!!**
- **Therefore, <u>use your judgment</u> as of what matches to select!!**

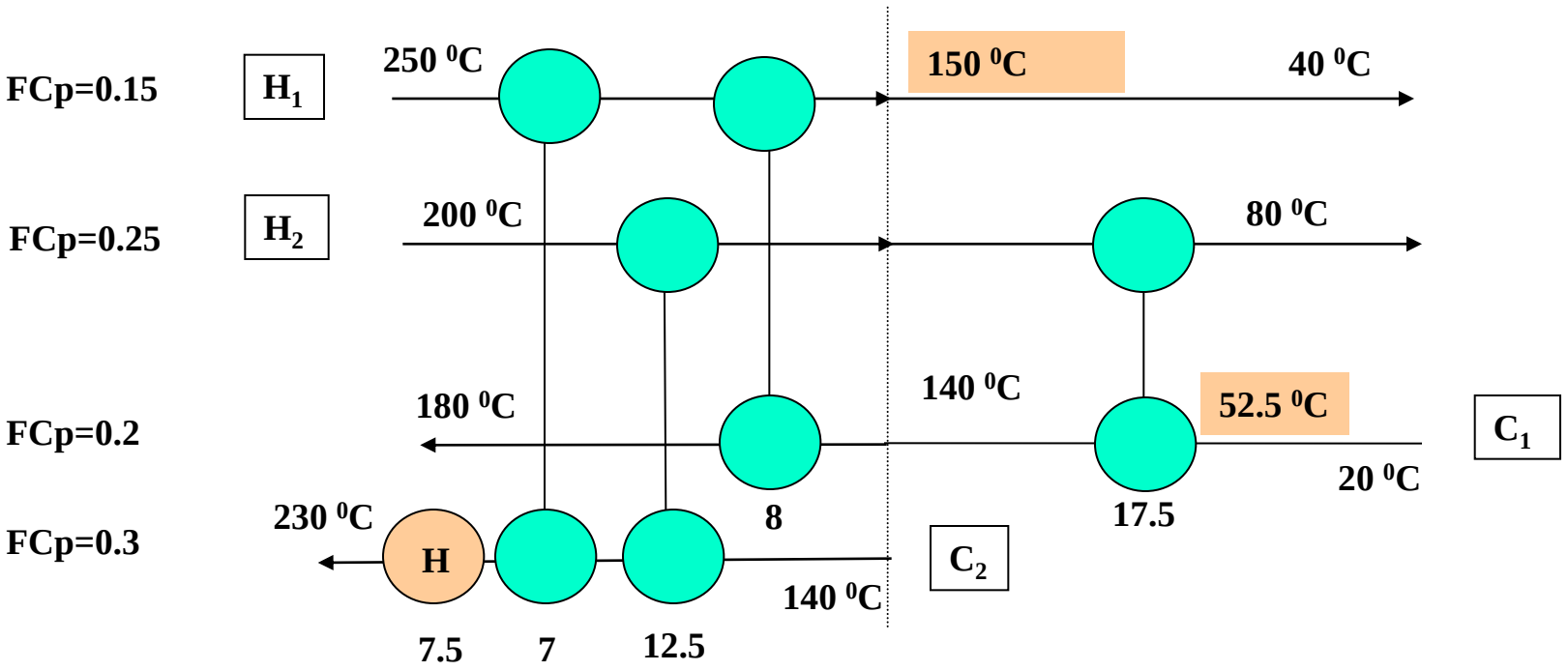
NON-PINCH MATCHES



- **We first note that we will use heating above the pinch. Thus all hot streams need to reach their inlet temperature. We are then forced to look for a match for H1.**

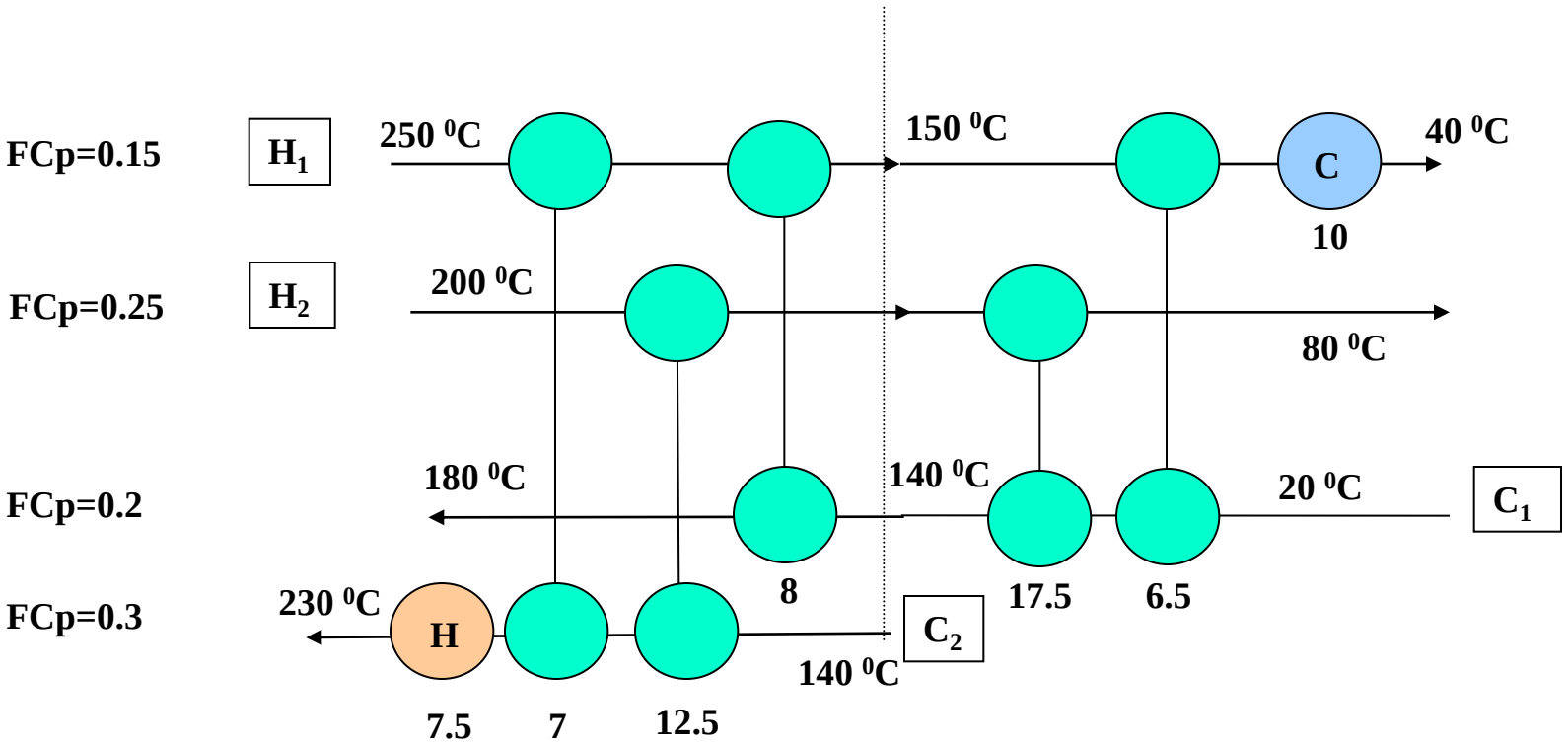
NON-PINCH MATCHES

- The match is H1-C1. We finally put a heater on the cold stream



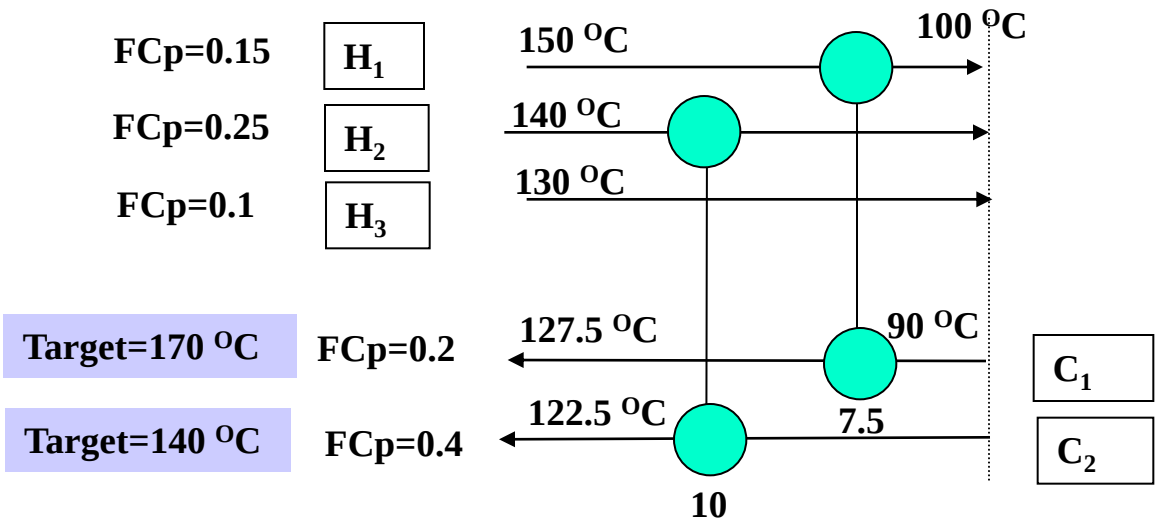
NON-PINCH MATCHES

- **Below the pinch we try to have the cold streams start at their inlet temperatures and we later locate coolers (one in this case).**



UNEQUAL NUMBER OF STREAMS AT THE PINCH

Indeed, if the number of hot streams is larger than the number of cold streams, then no pinch matches are possible. Consider this (new) example:

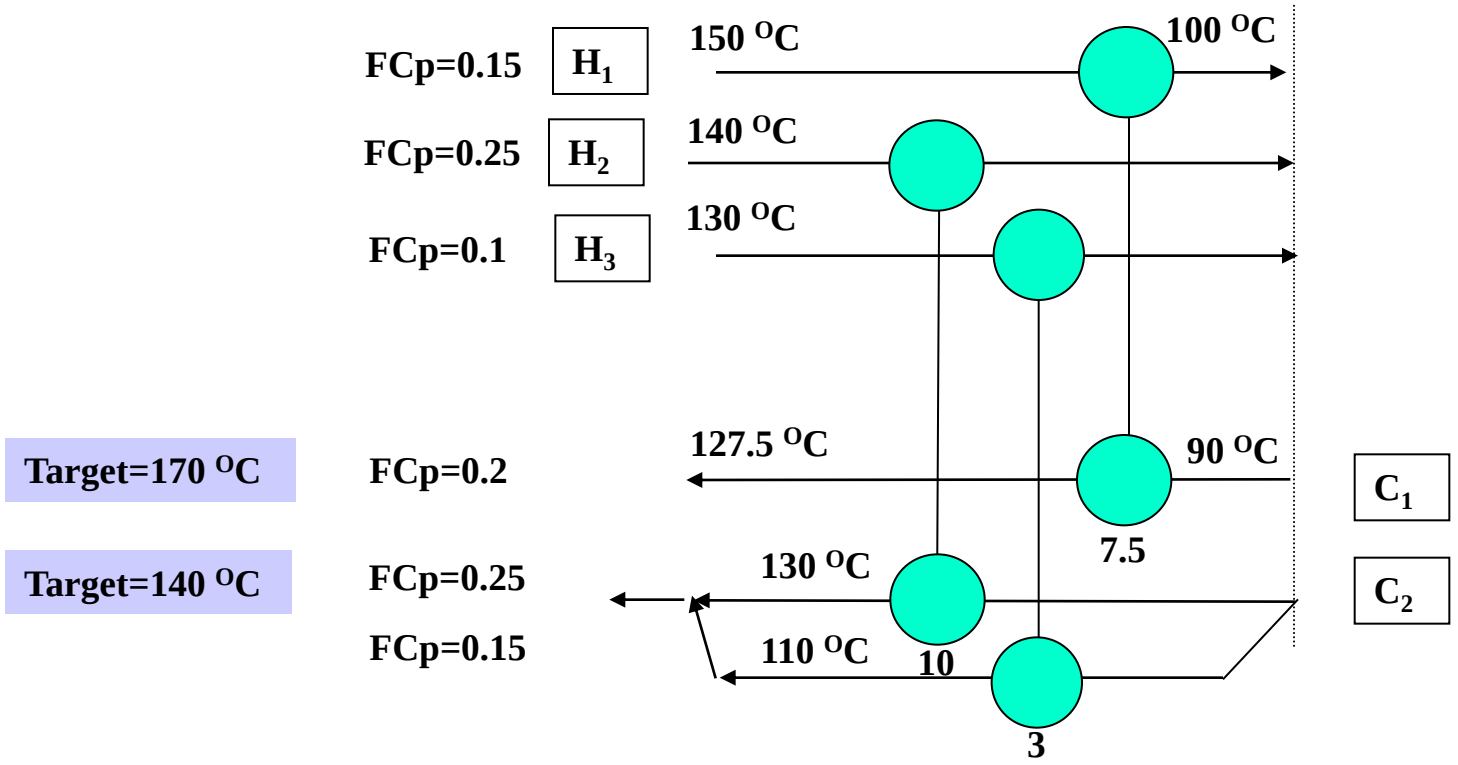


Assume the matches H_1-C_1 and the matches H_2-C_2 have been selected. Since H_3 needs to go to the pinch temperature, there is no cold stream left to match, even if there is portions of C_1 or C_2 that are left for matching. Such matching would be infeasible.

What is then, the solution?

UNEQUAL NUMBER OF STREAMS AT THE PINCH

Split cold stream until the inequality is satisfied.



Notice that different combinations of flowrates in the split satisfy the inequality.

UNEQUAL NUMBER OF STREAMS AT THE PINCH

Above the pinch, we notice the following rule

$$S_H \leq S_C$$

If that is NOT the case, we split a cold stream until $S_H = S_C$

A similar rule can be discussed below the pinch, that is,

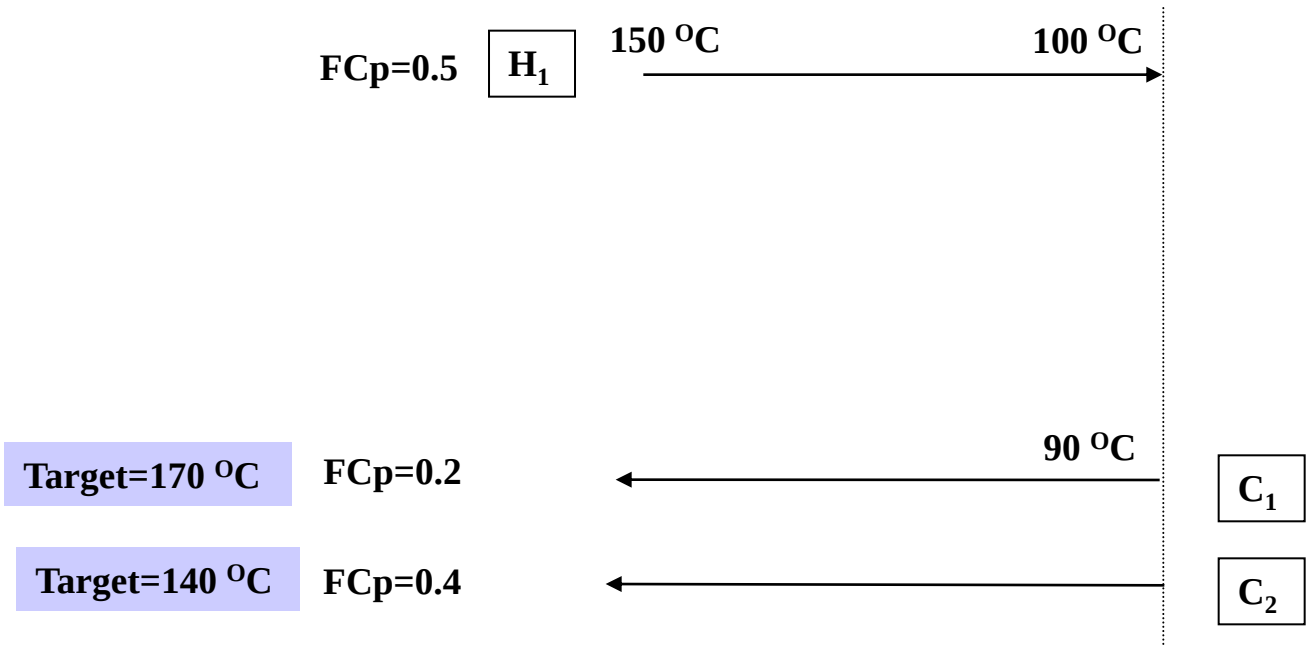
$$S_H \geq S_C$$

If that is NOT the case, we split a cold stream until $S_H = S_C$

INEQUALITIES NOT SATISFIED

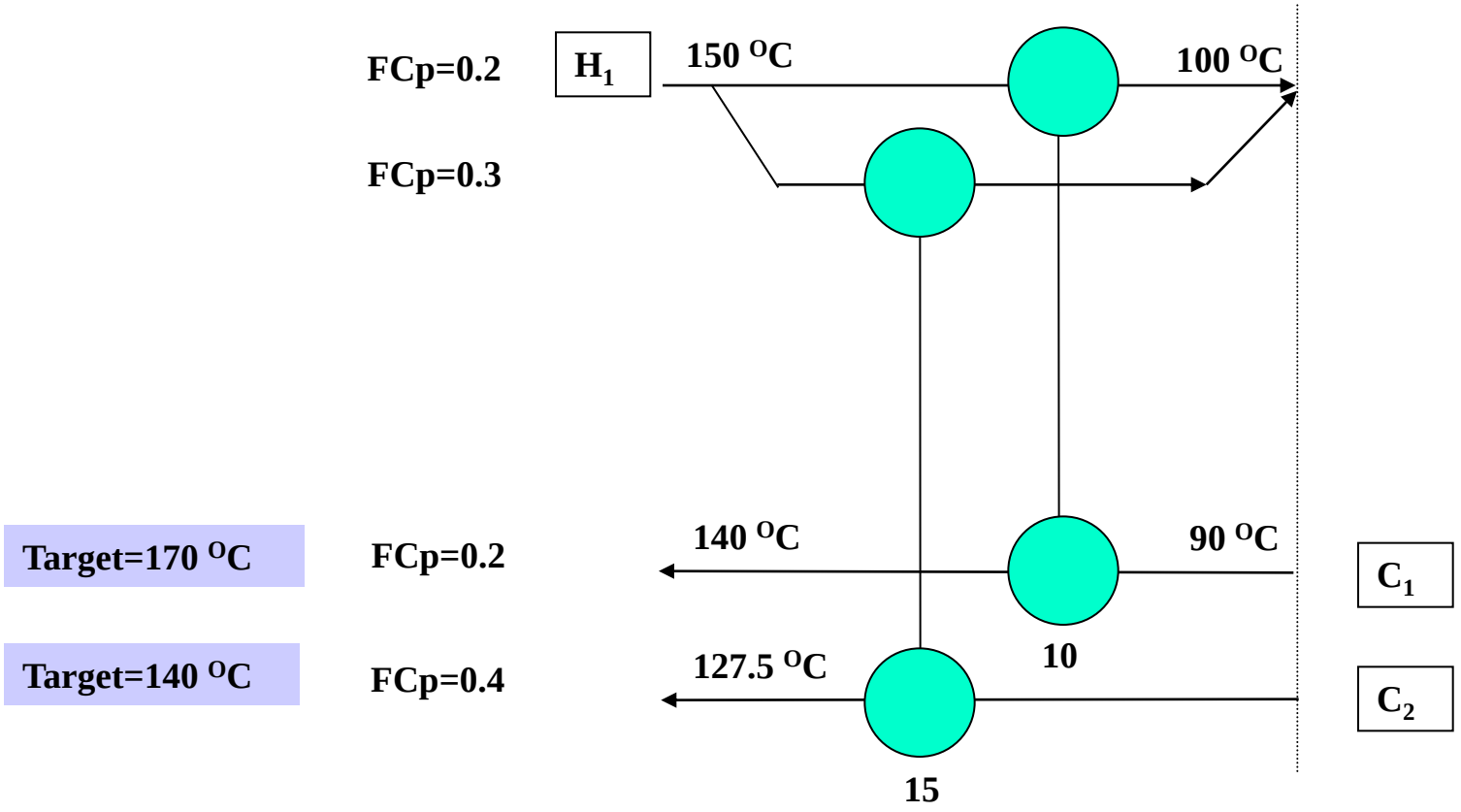
Consider the following caseabove the pinch

We notice that $FCp_H > FCp_C$ (needs to be $FCp_H \leq FCp_C$)



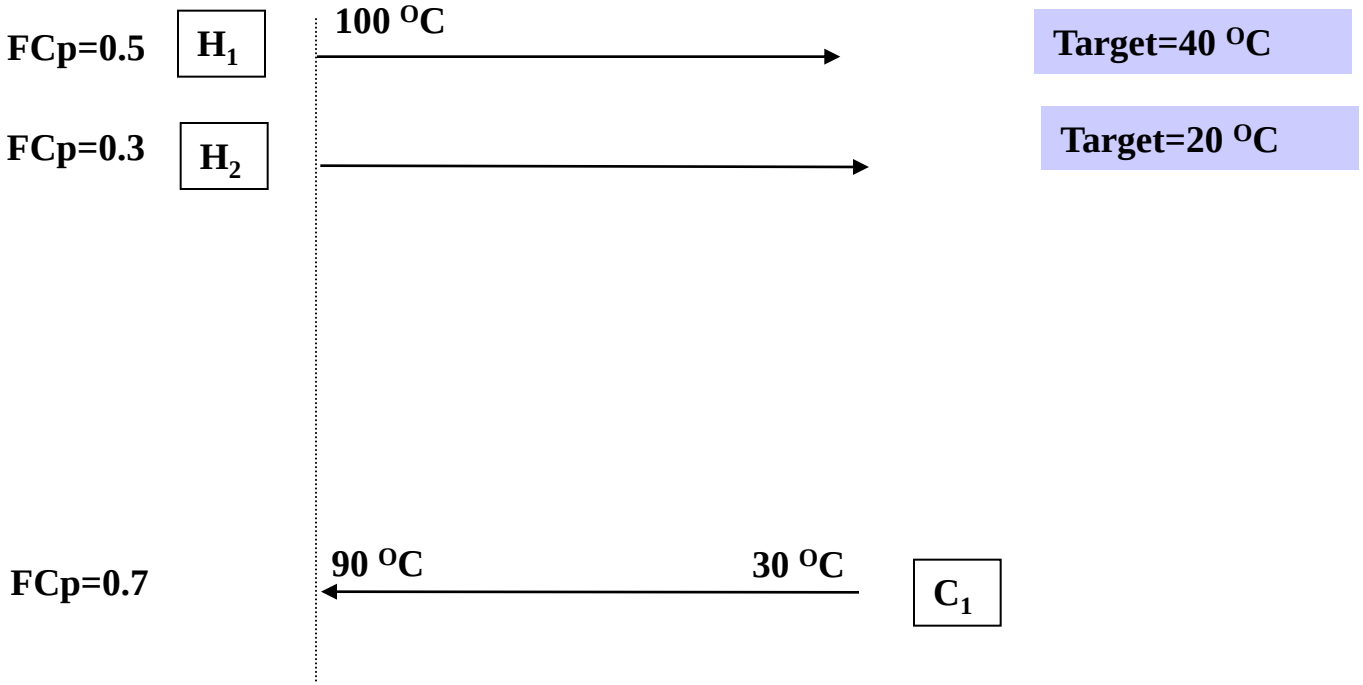
INEQUALITIES NOT SATISFIED

The hot stream needs to be split



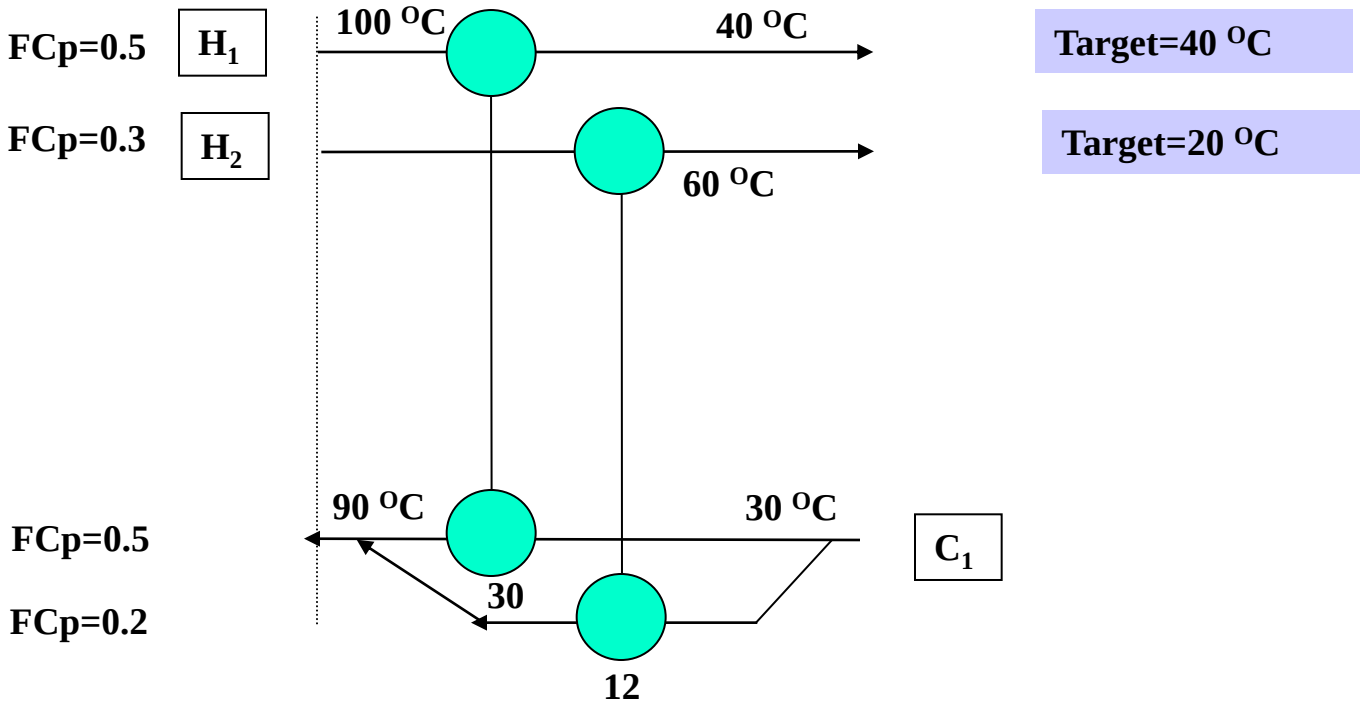
INEQUALITIES NOT SATISFIED

Below the Pinch :



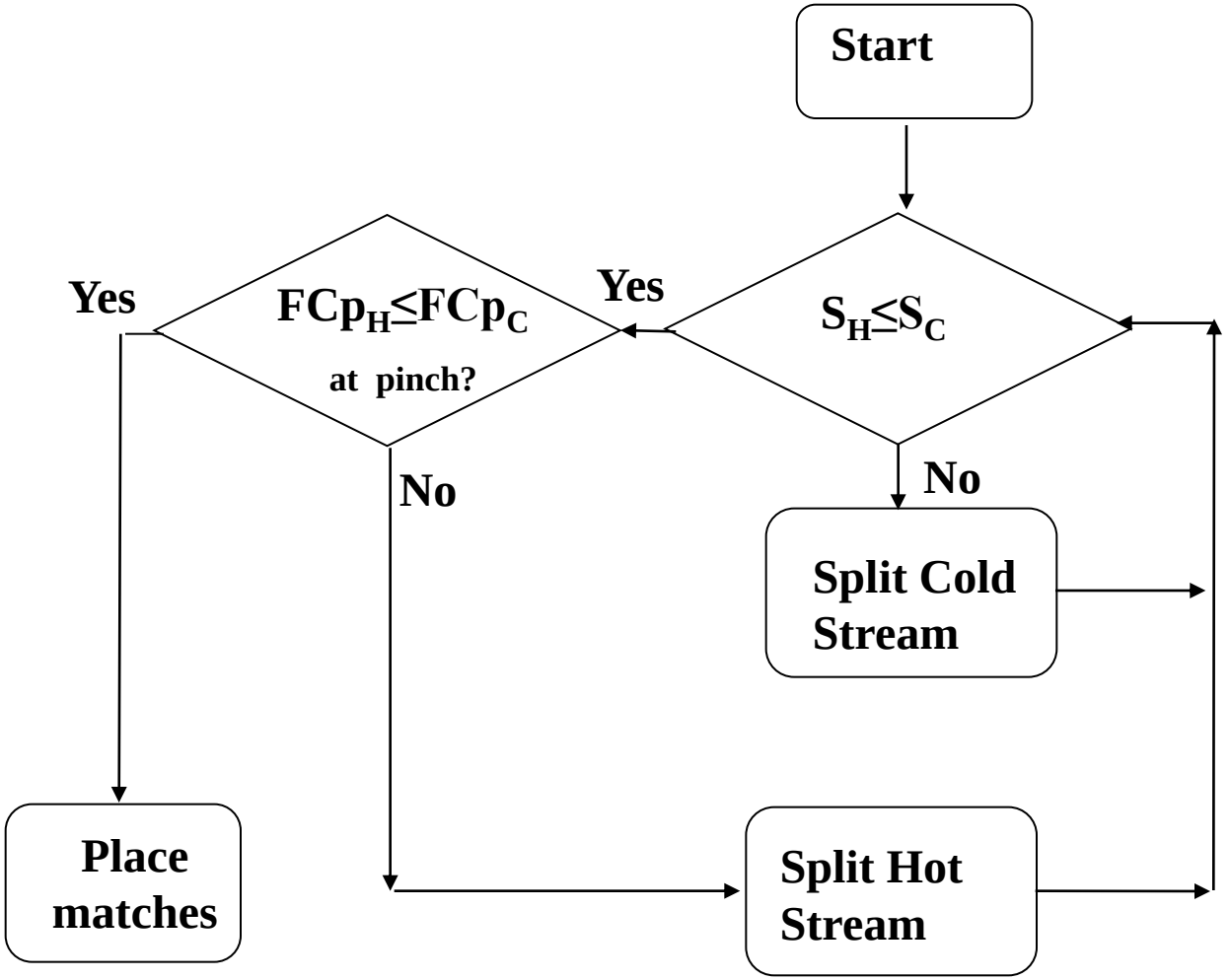
INEQUALITIES NOT SATISFIED

The cold stream needs to be split



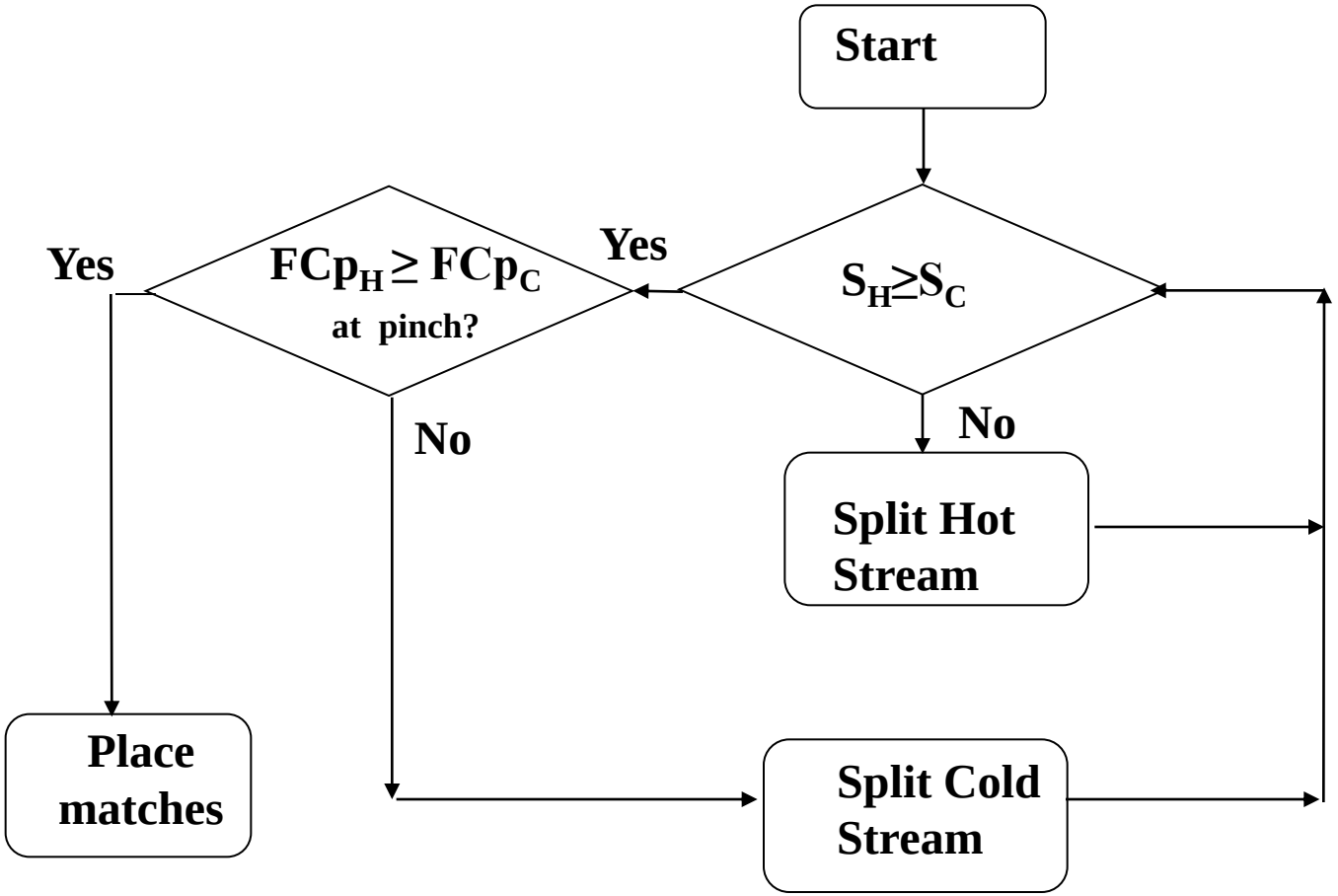
COMPLETE PROCEDURE

ABOVE THE PINCH



COMPLETE PROCEDURE

BELOW THE PINCH



HANDS ON EXERCISE

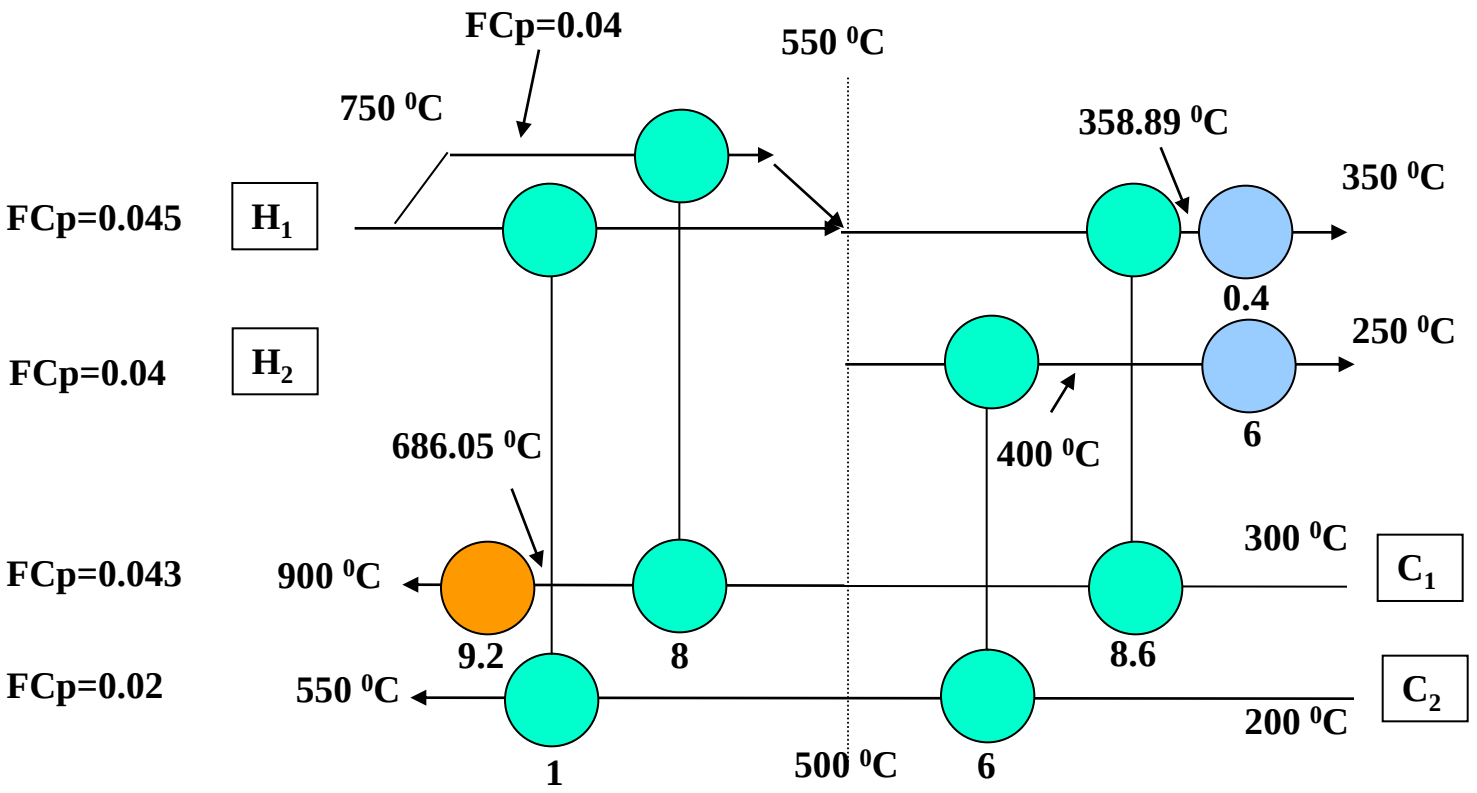
Type	Supply T (^oC)	Target T (^oC)	F*Cp (MW $^oC^{-1}$)
Hot	750	350	0.045
Hot	550	250	0.04
Cold	300	900	0.043
Cold	200	550	0.02

ΔT_{min}=50 ^oC

Minimum Heating Utility= 9.2 MW

Minimum Cooling Utility= 6.4 MW

ANSWER

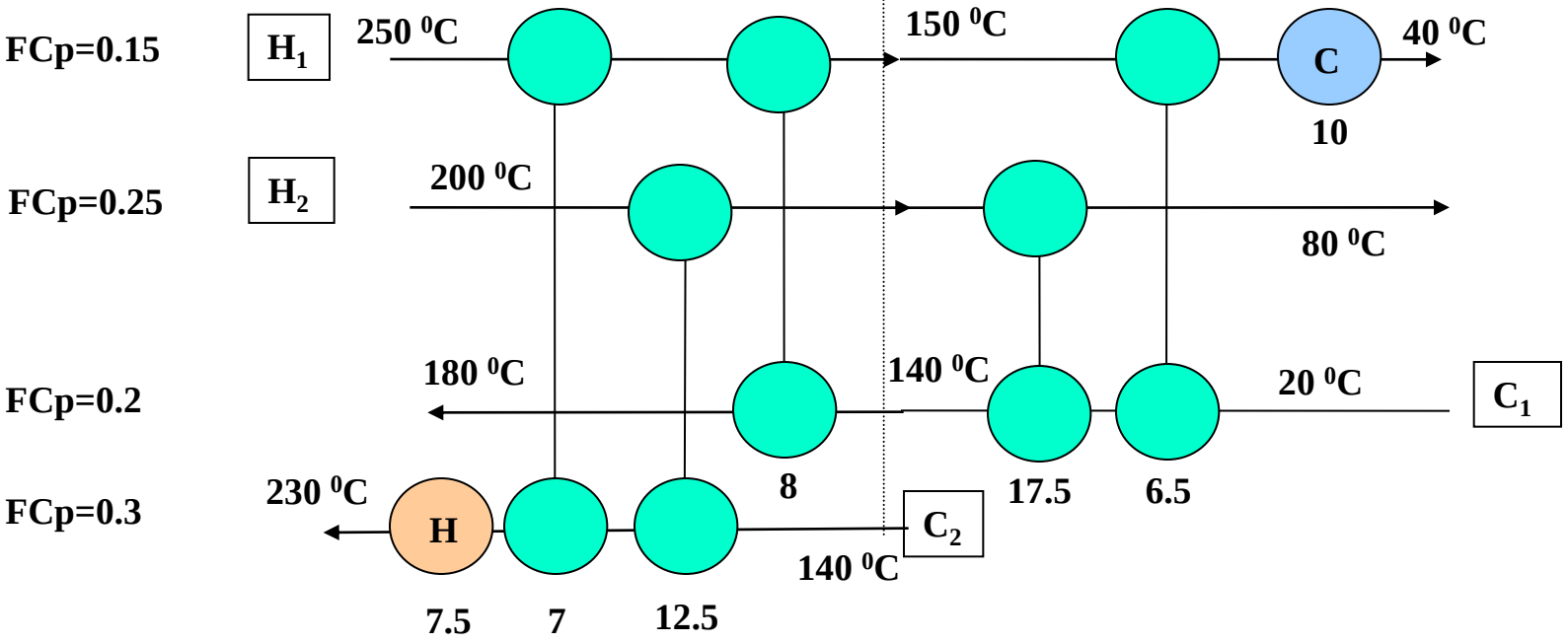

FCp=0.04
550 ^{0}C
750 ^{0}C
358.89 ^{0}C
350 ^{0}C
FCp=0.045
H_1
0.4
250 ^{0}C
FCp=0.04
H_2
6
686.05 ^{0}C
400 ^{0}C
300 ^{0}C
FCp=0.043
900 ^{0}C
C_1
9.2
8
8.6
FCp=0.02
550 ^{0}C
C_2
200 ^{0}C
1
500 ^{0}C
6

NOTE ON UNIT TARGETING

$$N_{min} = (S\text{-}P)_{\text{above pinch}} + (S\text{-}P)_{\text{below pinch}}$$

If we do not consider two separate problems, above and below the pinch we can get misleading results.

EXAMPLE



$$N_{min} = (S-P)_{\text{above pinch}} + (S-P)_{\text{below pinch}} =$$

$$=(5-1) + (4-1) = 7$$

If we do not consider two separate problems

Nmin= (6-1)= 5, which is most of the time wrong

Note: A heat exchanger network with 5 exchangers exists, but it is impractical and costly. This is beyond the scope of this course.